United States Patent [19]

Shea et al.

[11] **Patent Number:** **4,983,939**

[45] **Date of Patent:** **Jan. 8, 1991**

[54] CIRCUIT BREAKER WITH ADJUSTABLE LOW MAGNETIC TRIP

[75] Inventors: **John J. Shea**, Monroeville; **Richard P. Sabol**, Munhall; **Louis Paich**, Center Township; **Ronald A. Cheski**, Stowe Township; **Kenneth W. Sanner**, Ohioville; **William E. Beatty, Jr.**, Brighton Township, all of Pa.

[73] Assignee: **Westinghouse Electric Corp.**, Pittsburgh, Pa.

[21] Appl. No.: **417,360**

[22] Filed: **Oct. 5, 1989**

[51] **Int. Cl.**[5] **H01H 75/10**

[52] **U.S. Cl.** **335/42**; 335/172; 335/176

[58] **Field of Search** 335/42, 176, 45, 43.4, 335/8-10, 172

[56] **References Cited**

U.S. PATENT DOCUMENTS

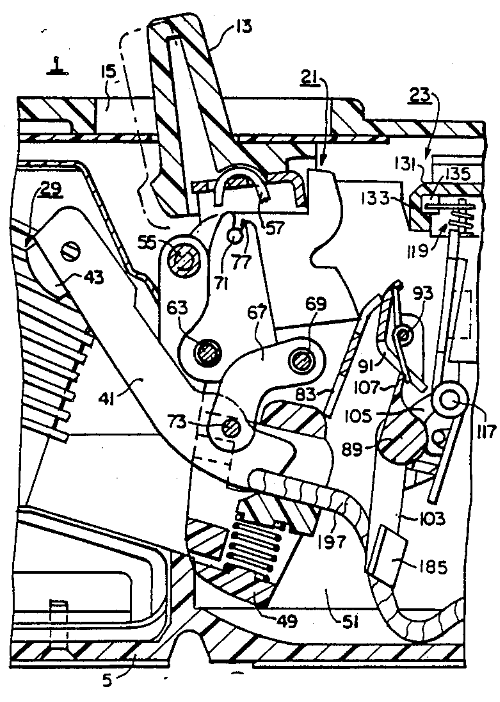
4,249,151	2/1981	Esteves	335/42
4,249,152	2/1981	Vazquez	335/42
4,630,019	12/1986	Maier et al.	
4,691,182	9/1987	Mrenna et al.	

Primary Examiner—Leo P. Picard
Assistant Examiner—L. Donovan
Attorney, Agent, or Firm—M. J. Moran

[57] **ABSTRACT**

A circuit breaker has a magnetic trip assembly which can be adjusted to trip the breaker for low level overcurrents in the range of five to ten times rated current. The magnet trip includes for each pole of the breaker a helical torsion spring having one torsion arm which biases an armature against an adjusting bar to form a gap between the armature and a stationary magnetic structure in which magnetic flux strong enough to attract the armature and trip the breaker is induced by overcurrent. A second torsion arm of the spring has a first portion which bears against and slides along a pivot member carried by the adjusting bar to adjust the bias force applied to the armature by a given amount per unit travel of the adjusting bar over a low trip current portion of the range of travel of the adjusting bar. A second terminal portion of the second torsion arm of the spring extending at an angle from the first portion engages and slides along the pivot member on the adjusting bar to provide a greater change of bias force per unit travel of the adjusting bar at the higher trip current settings. Movement of the adjusting bar adjusts the spring bias for all poles of a multiphase circuit breaker simultaneously. The gaps between the armatures and the fixed magnetic structures of all the poles can also be adjusted by camming surfaces on the adjusting bar.

15 Claims, 7 Drawing Sheets



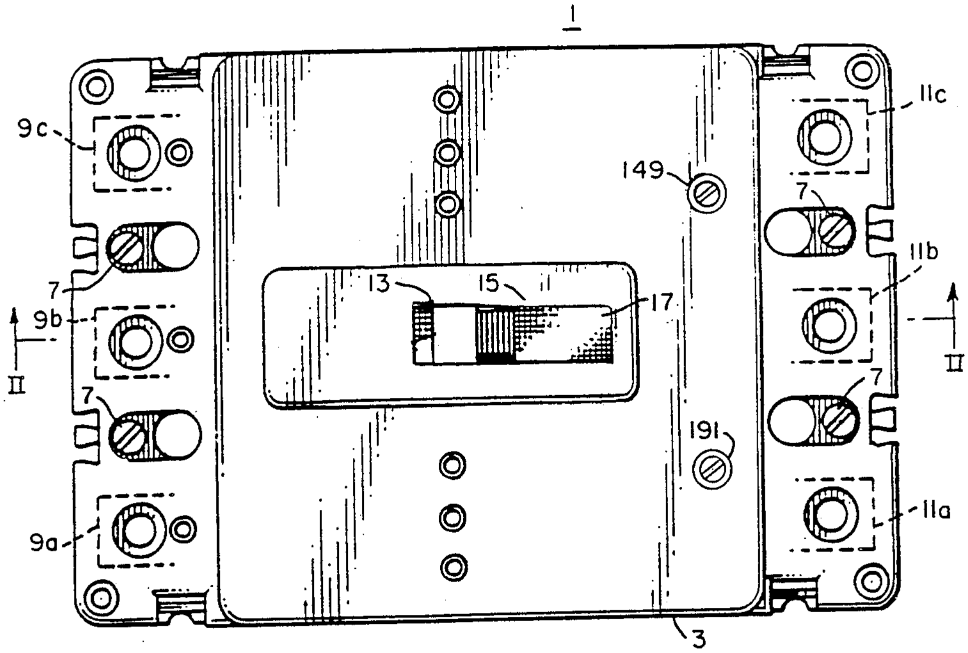


FIG. 1

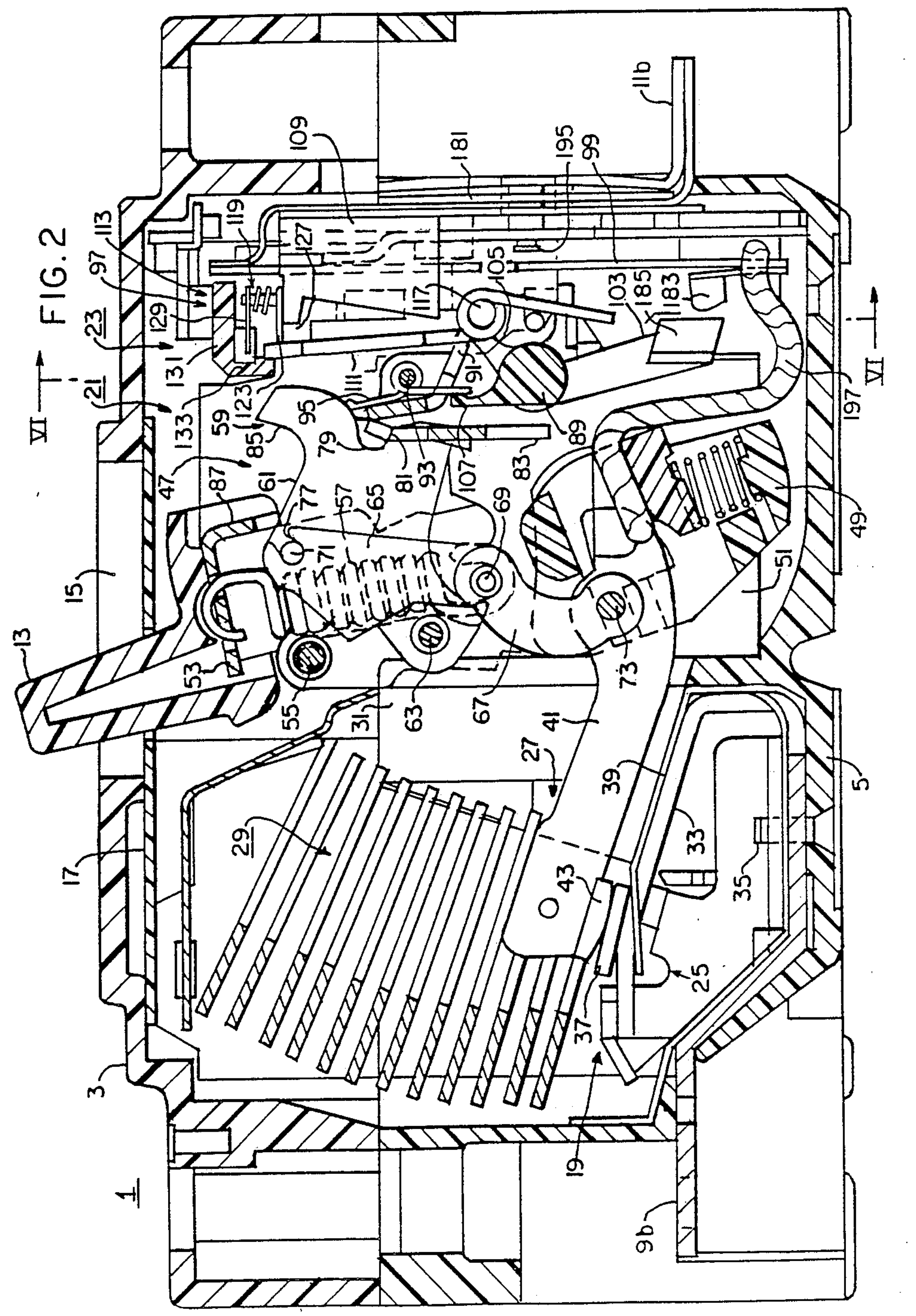
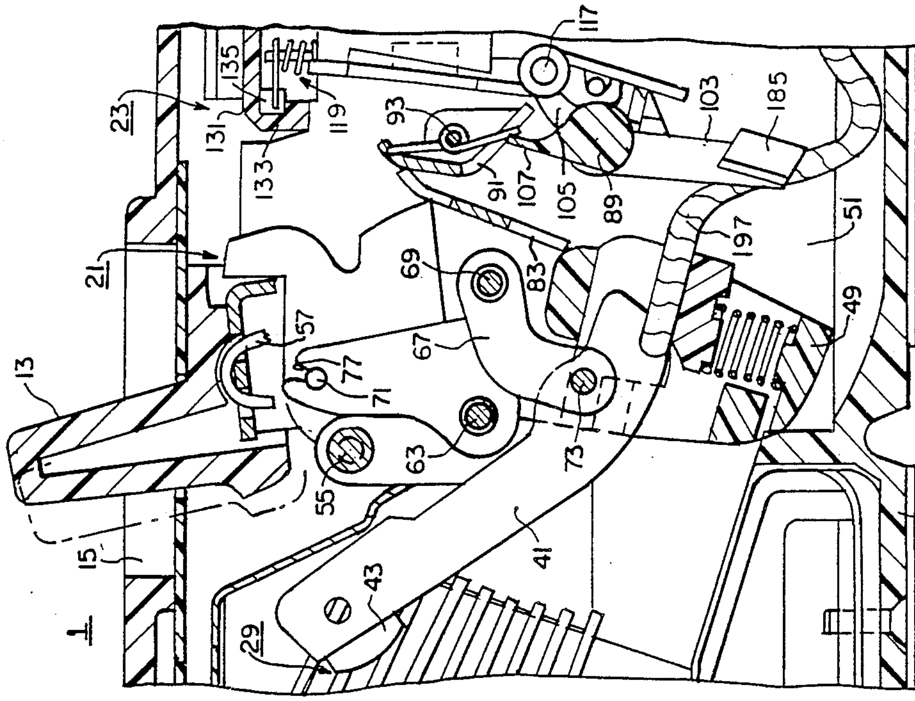
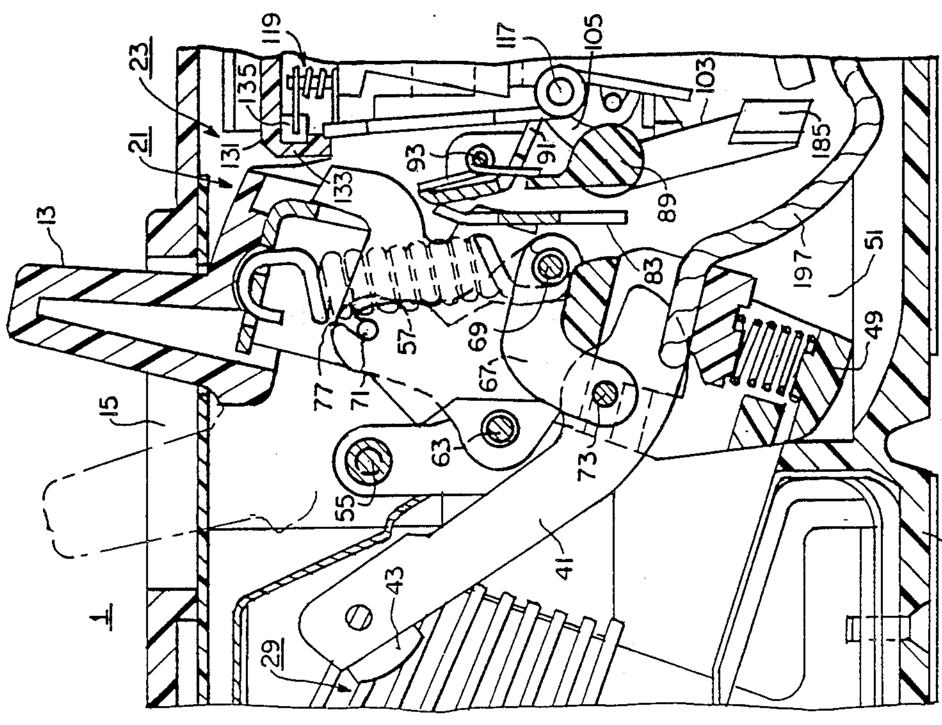


FIG. 2



1
5
13
15
21
23
29
41
43
49
51
55
57
63
67
69
71
73
77
83
89
91
93
103
105
107
117
119
131
133
135
185
197

FIG. 4



1
5
13
15
21
23
29
41
43
49
51
55
57
63
67
69
71
73
77
83
89
91
93
103
105
117
119
131
133
135
185
197

FIG. 3

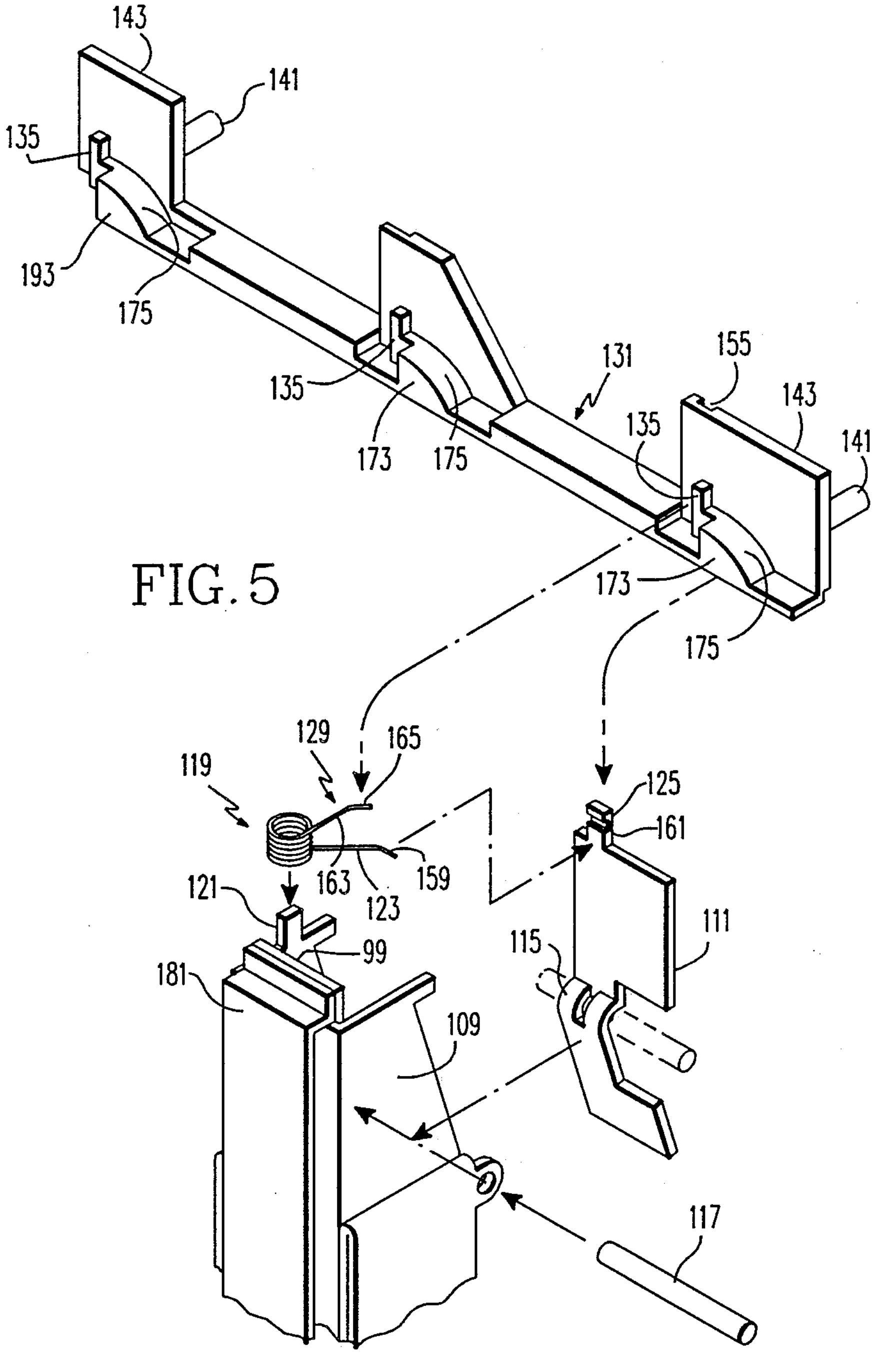

143
141
135
193
175
135
173
175
131
155
143
135
141
173
175
129
165
119
125
161
163
159
123
121
99
111
115
181
109
117

FIG. 5

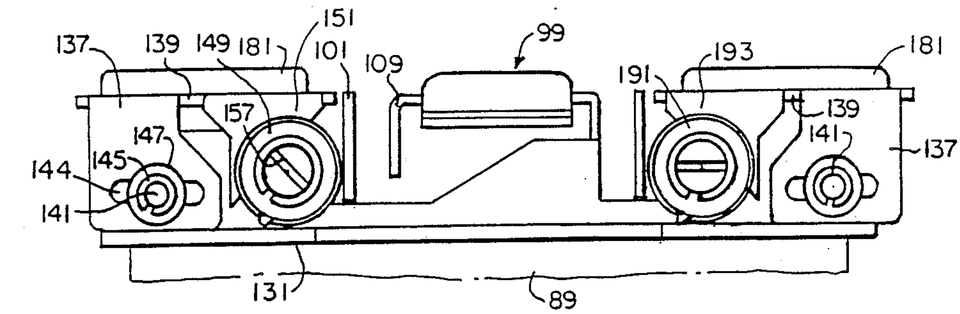

151
137
139
149
181
101
109
99
193
181
191
139
157
141
147
137
144
145
141
131
89

FIG. 7

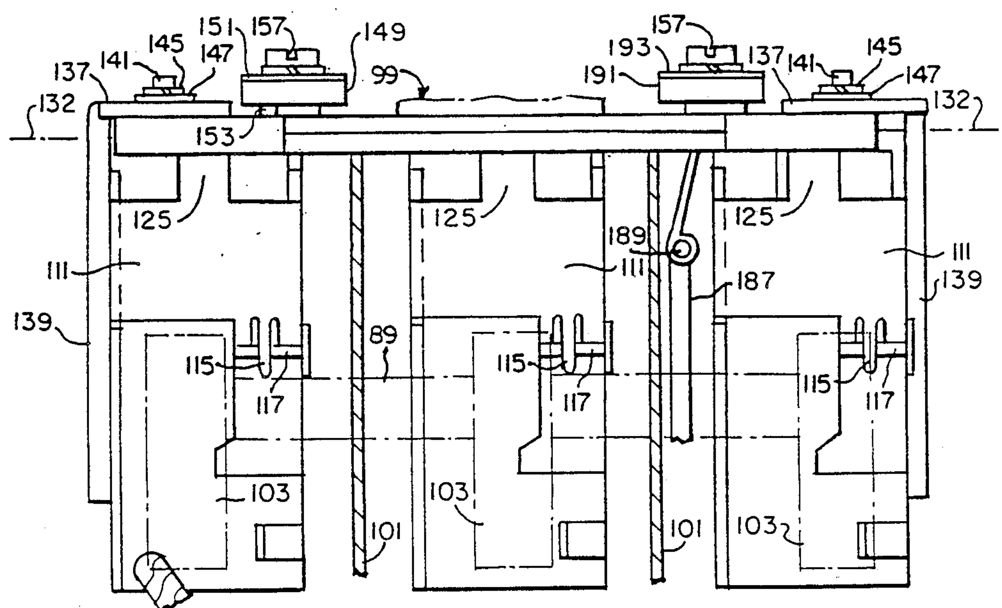

151
157
149
157
193
137
141
145
147
99
191
137
141
145
147
132
153
132
125
125
125
189
111
111
111
139
187
139
89
115
117
115
117
115
117
103
103
101
101
103

FIG. 6

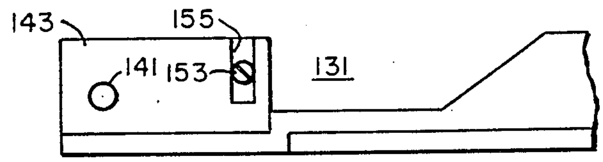


FIG. 8

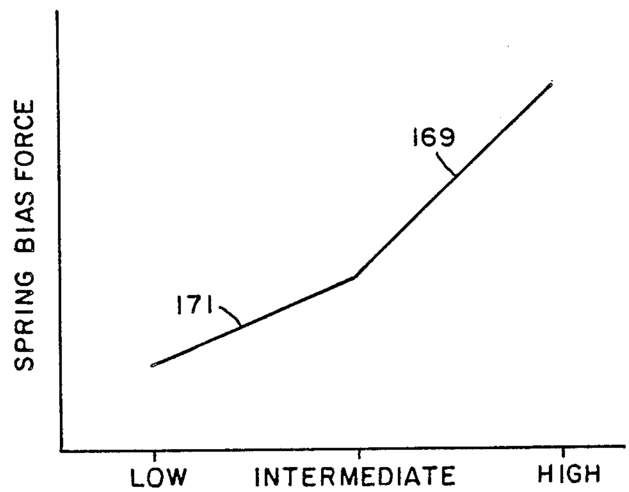


FIG. 11

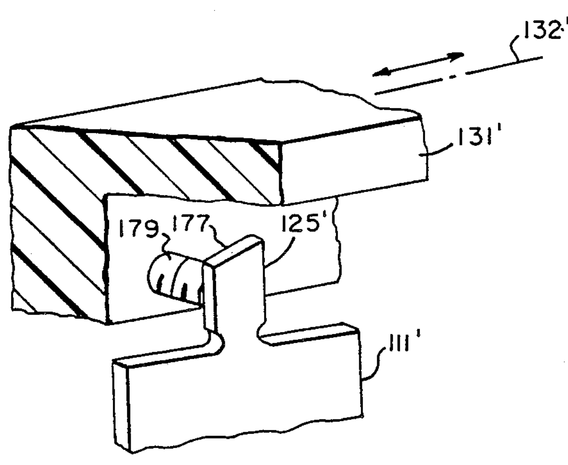


FIG. 12

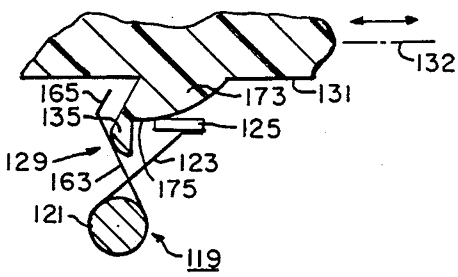


FIG. 9A

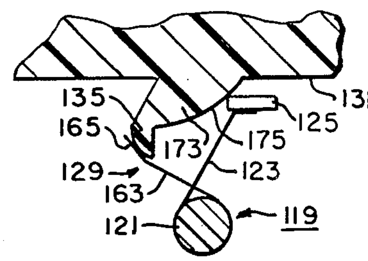


FIG. 9B

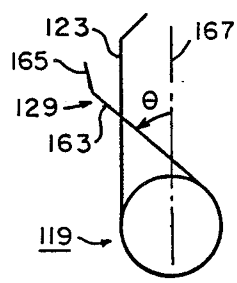


FIG. 10A

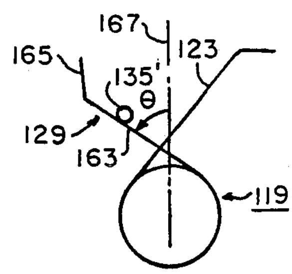


FIG. 10B

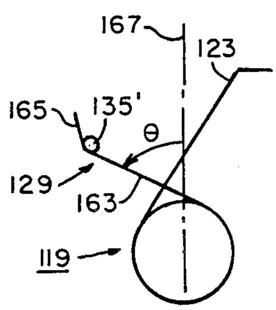


FIG. 10C

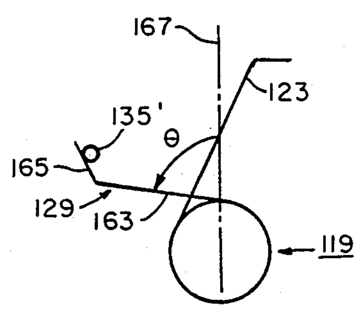


FIG. 10D

CIRCUIT BREAKER WITH ADJUSTABLE LOW MAGNETIC TRIP

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

This invention relates to circuit breakers with a magnetic trip assembly including an armature which is biased by a spring to form a gap with a fixed magnetic structure and which is attracted toward the fixed magnetic structure to trip the breaker by magnetic flux produced by abnormal current. In particular, the invention relates to circuit breakers having such a trip assembly which includes mechanisms for adjusting the spring bias and the gap to modify the level of current at which the breaker trips.

BACKGROUND INFORMATION

Circuit breakers provide protection for electrical systems from electrical fault conditions such as current overloads and short circuits. Typically, circuit breakers include a spring powered, latchable operating mechanism which opens electrical contacts to interrupt the current through the conductors on an electrical system in response to abnormal currents. The operating mechanism is latched by a trip bar which in turn is operated by a trip mechanism associated with each phase of the electrical system. Typically, the trip mechanism includes a thermal trip device which responds to persistent low levels of overcurrent and a magntic trip device which responds instantaneously to higher levels of overcurrent. The magnetic trip device comprises for each pole a fixed magnetic structure energized by the current flowing through the conductor, and a moveable armature which is attracted toward the stationary magnetic structure to operate the trip bar. The trip bar in turn unlatches the operating mechanism which opens the electrical contacts in each phase of the electrical system. Each moveable armature is biased away from the associated stationary magnetic structure by a spring to form a gap between the armature and the stationary magnetic structure in the absence of a abnormal current.

Usually, means are provided for adjusting the level of current at which the magnetic trip device actuates the operating mechanism. Such adjustments can be made by varying the spring bias applied to the armature and/or by mechanically adjusting the gap such as by varying the position of a threaded screw or cam against which the spring biases the armature These adjustments permit fine tuning of the circuit breaker to assure that it will operate at the desired level of fault current. They can also be used to provide a range of settings at which the circuit breaker will trip.

U.S. Pat. No. 4,691,182 is an example of a circuit breaker having means for adjusting the spring bias and the gap for each pole of the breaker. The spring bias is adjusted individually for each pole by a rotatable cam which pivots a lever to adjust the bias applied to a rotatable armature by a tension spring. A threaded screw provides individual adjustment of the gap between the armature and the stationary magnetic structure.

U.S. Pat. No. 4,630,019 discloses a circuit breaker in which the armature of the magnetic trip device is biased by a helically wound torsion spring. The spring bias may be adjusted by engaging one arm of the torsion spring in one of a number of slots in a support plate.

For the most part, the above mentioned circuit breakers trip magnetically at currents which are about 15 to 20 times the rated currents of the breaker. Recently there has developed an interest for such circuit breakers with a trip assembly which operates at lower levels of instantaneous overcurrent. In particular, magnetic trips at about 5 to 10 times the rated current of the breaker are desired. While the above aforementioned circuit breakers provide good adjustability within their operating ranges, they cannot for the most part be adjusted to operate effectively at the desired lower tripping levels of 5 to 10 times breaker rating. The major obstacles are insufficient force to trip the breaker at the required low current levels, limited magnetic trip range due to space limitations on adjusting bar movement, and tolerances. However, such circuit breakers have been in use for many years and their design has been refined to provide an effective, reliable circuit breaker which can be easily and economically manufactured on a large scale.

There is a need therefore for circuit breakers which can reliably operate at low magnetic trip currents.

There is a related need for modifying existing proven circuit breaker designs to operate at the new lower magnetic tripping current levels.

There is a further need for such modifications which require minimum changes to the existing circuit breakers, and which can be easily and economically applied.

SUMMARY OF THE INVENTION

These and other needs are satisfied by the invention which is directed to a circuit breaker with a magnetic trip assembly which includes a spring applying a biasing force to the armature to bias it away from the fixed magnetio structure and spring adjustment means moveable over a range of travel for adjusting the biasing force to modify the value of abnormal current at which the armature is attracted to the fixed magnetic structure to unlatch the circuit breaker latchable operating mechanism. The spring adjusting means provides a first relationship between movement of the spring adjusting means and change in the biasing force over a first portion of the range of travel of the adjusting means, and provides a second relationship between movement of the spring adjusting means and change in the biasing force over a second portion of the range of travel of the spring adjusting means. The spring adjusting means adjusts the biasing force in this manner simultaneously for all three poles.

More particularly, the spring is a torsion spring having a first torsion arm which bears against and applies the bias force to the armature, and a second torsion arm having a first portion and a second terminal portion extending at an angle to the first portion. The spring adjusting means comprise's a pivot member which is mounted for reciprocal movement over the range of travel of the adjusting means. The first portion of the second torsion arm engages and slides along the pivot member for the first portion of the range of travel of the spring adjusting means and the second terminal portion of the second torsion arm engages and slides along the pivot member for the second portion of the range of travel of the spring adjusting means. The angle which the second portion of the second torsion arm makes with an adjustment axis along which the pivot member reciprocates is greater than the angle that the first portion of the second torsion arm makes with this adjustment axis so that movement of the adjusting means over the second portion of its range of travel produces a greater change in the bias force per unit travel than does movement of the adjusting member over the first portion of its range of travel. This Provides the greater relative change required for adjusting the trip current from between about five and ten times the circuit breaker rating as compared with adjusting the range between 15 and 20 times the breaker rating.

As another aspect of the invention, the adjustment bar carries means for adjusting the gap between the armature and the fixed magnetic structure. In one embodiment cams are provided on the adjusting bar against which the armatures are biased by the springs. Rectilinear movement of the adjusting bar adjusts the portion of the camming surface of the cam against which the armature bears and therefore varies the gap. Alternatively, a camming surface can be provided on the armature as by twisting a tab on a planar armature. A projection on the adjusting bar moves along the camming surface to adjust the gap. Preferably, the projection is a screw so that gap may be set independently for each pole. Also preferably, the second portion of the second torsion of the biasing spring engages the pivot member when the gap is at the high end of its range.

BRIEF DESCRIPTION OF THE DRAWINGS

A full understanding of the invention can be gained from the following description of the preferred embodiments when read in conjunction with the accompanying drawings in which:

FIG. 1 is a plan view of a circuit breaker incorporating the invention.

FIG. 2 is an enlarged vertical section through the circuit breaker of FIG. 1 taken along the line to 2 in FIG. 1 and illustrating the circuit breaker in the closed position with the blown open position shown in phantom.

FIG. 3 is an enlarged vertical section of a portion of the circuit breaker of FIG. 1 taken along the same line as FIG. 2 but showing the circuit breaker in the open position.

FIG. 4 is an enlarged vertical section of a portion the circuit breaker of FIG. 1 taken along the same line as FIGS. 2 and 3 but showing the circuit breaker in the tripped position.

FIG. 5 is an exploded isometric view of a magnetic trip assembly in accordance with the invention.

FIG. 6 is a vertical cross section through the circuit breaker of the invention taken along the line 6—6 in FIG. 1.

FIG. 7 is a plan view of the portion of the circuit breaker shown in FIG. 6.

FIG. 8 is a fragmentary view of a portion of FIG. 7 with parts removed.

FIGS. 9A and 9B are partial horizontal sections showing engagement of a spring with an armature and with the adjustment bar for a low setting and a high setting of the circuit breaker of FIG. 1 respectively.

FIGS. 10A, 10B, 10C, and 10D illustrate schematically a spring used in a circuit breaker of the invention in the free position, a low setting position, an intermediate setting position, and a high setting position, respectively.

FIG. 11 is a plot of bias force versus adjustment bar movement for the spring shown in FIGS. 9 and 10.

FIG. 12 is a horizontal section through a portion of another embodiment of a circuit breaker in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings, there is illustrated a molded case circuit breaker **1** incorporating a magnetic trip assembly with the improved means for adjusting the trip set point in accordance with the teachings of the invention. While the circuit breaker **1** is depicted and described herein as a three-phase, or three-pole circuit breaker, the principles of the invention are equally applicable to single phase or polyphase circuit breakers, and to both ac and dc circuit breakers.

The circuit breaker **1** includes a molded, electrically insulting, top cover **3** mechanically secured to a molded, electrically insulating, bottom cover or base **5** by fasteners **7**. A set of first electrical terminals, or line terminals **9*a*, 9*b*** and **9*c*** are provided, one for each pole or phase. Similarly, a set of second electrical terminals, or load terminals **11*a*, 11*b*** and **11*c*** are provided at the other end of the circuit breaker base **5**. These terminals are used to serially electrically connect circuit breaker **1** into a three-phase electrical circuit for protecting a three-phase electrical system.

The circuit breaker **1** further includes an electrically insulating, rigid, manually engagable handle **13** extending through an opening **15** in the top cover **3** for setting the circuit breaker **1** to its CLOSED position (FIG. 2 or its OPEN position (FIG. 3). The circuit breaker **1** may also assume a TRIPPED position (FIG. 4). Circuit breaker **1** may be reset from the TRIPPED position to the CLOSED position for further protective operation by moving the handle **13** through the open position (FIG. 3). The handle **13** may be moved either manually or automatically by an operating mechanism **21** to be described in more detail. Preferably, an electrically insulating strip **17**, movable with the handle **13**, covers the bottom of the opening **15**, and serves as an electrical barrier between the interior and the exterior of the circuit breaker **1**.

As its major internal components, the circuit breaker **1** includes a set of electrical contacts **19** for each phase, an operating mechanism **21** and a trip mechanism **23**. Each set of electrical contacts includes a lower electrical contact **25** and an upper electrical contact **27**. Associated with each set of electrical contacts **19** are an arc chute **29** and a slot motor **31** both of which are conventional. Briefly, the arc chute **29** divides a single electrical arc formed between separating electrical contacts **25** and **27** upon a fault condition into a series of electrical arcs, increasing the total arc voltage and resulting in a limiting of the magnitude of the fault current. The slot motor **31**, consisting of either of a series of generally U-shaped steel laminations encased in electrical insulation or of a generally U-shaped electrically insulated, solid steel bar, is disposed about the contacts **25, 27**, to concentrate the magnetic field generated upon a high level short circuit or fault current condition thereby greatly increasing the magnetic repulsion forces between the separating electrical contacts **25** and **27** to rapidly accelerate their separation. The rapid separation of the electrical contracts **25** and **27** results in a relativelyhigh arc resistance to limit the magnitude of the fault current. A more detailed description of the arc chute **29** and slot motor **31** can be found in U.S. Pat. No. 3,815,059.

The lower electrical contact **25** includes a U-shaped stationary member **33** secured to the base **5** by a fastener **35**, a contact **37** for physically and electrically contacting the upper electrical contact **27** and an electrically insulating strip **39** to reduce the possibility of arcing between the upper electrical contact **27** and portions of the lower electrical contact **25**. The line terminal **9** extending exteriorly of the base **5** comprises an integral end portion of the member **33**.

The upper electrical contact **27** includes a rotatable contact arm **41** and a contact **43** for physically and electrically contacting the lower electrical contact **25**.

The operating mechanism **21** includes an over-center toggle mechanism **47**, an integral one-piece molded cross bar **49**, a pair a rigid, spaced apart, metal side plates **51**, a rigid, pivotable metal handle yoke **53**, a rigid stop pin **55**, a pair of operating tension springs **57** and a latching mechanism **59**.

The over-center toggle mechanism **47** includes a rigid, metal cradle **61** that is rotatable about the longitudinal central axis of a cradle support pin **63** journaled in the side plates **51**.

The toggle mechanism **47** further includes a pair of upper toggle links **65**, a pair of lower toggle links **67**, a toggle spring pin **69** and an upper toggle link follower pin **71**. The lower toggle links **67** are secured to either side of the rotatable contact arm **41** of the upper electrical contact **27** by toggle contact pin **73**. The ends of the pin **73** are received and retained in the molded cross bar **49**. Thus, movement of the upper electrical contact **27**, and the corresponding movement of the cross bar **49** are effected by movement of the lower toggle links **67**. In this manner, movement of the upper electrical contact **27** by the operating mechanism **21** in the center pole or phase of the circuit breaker **1** simultaneously, through the rigid cross bar **49**, causes the same movement in the electrical contacts **27** associated with the other poles or phases of the circuit breaker **1**.

The upper toggle links **65** and lower toggle links **67** are pivotally connected by the toggle spring pins **69**. The operating tension springs **57** are stretched between the toggle spring pin **69** and the handle yoke **53** such that the springs **57** remain under tension, enabling the operation of the over-center toggle mechanism **47** to be controlled by and be responsive to external movement of the handle **13**.

The upper links **65** also include recesses or grooves **77** for receipt and retention of pin **71**. Pin **71** passes through the cradle **61** at a location spaced by a predetermined distance from the axis of rotation of the cradle **61**. Spring tension from the springs **57** retains the pin **71** in engagement with the upper toggle links **65**. Thus, rotational movement of the cradle **61** effects a corresponding movement or displacement of the upper portions of the links **65**.

The cradle **61** has a slot or groove **79** defining a flat latch surface which is configured to engage a flat cradle latch surface formed in the upper end of an elongated slot or aperture **81** in a generally flat intermediate latch plate **83**. The cradle **61** also includes a generally flat handle yoke contacting surface **85** configured to contact a downwardly depending, elongated surface **87** formed on the upper end of the handle yoke **53**. The operating springs **57** move the handle **13** during a trip operation and the surfaces **85** and **87** locate the handle **13** in the TRIPPED position (FIG. 4) intermediate the CLOSED position (FIG. 2) and the OPEN position (FIG. 3) of the handle **13**, to indicate that the circuit breaker **1** has tripped. In addition, the engagement of the surfaces **85** and **87** resets the operating mechanism **21** subsequent to a trip operation by moving the cradle **61** in a clockwise direction against the bias of the operating springs **57** from its TRIPPED position (FIG. 4) to and past its OPEN position (FIG. 3) to enable the relatching of the latching surfaces on groove **79** and in aperture **81**.

Further details of the operating mechanism and its associated molded cross bar **49** can be gained from the description of the similar operating mechanism disclosed in U.S. Pat. No. 4,630,019.

The trip mechanism **23** includes the intermediate latch plate **83**, a molded one-piece trip bar **89**, a cradle latch plate **91**, a torsion spring support pin **93**, a double acting torsion spring **95**, a magnetic trip assembly **97** and a thermal trip device **99** in the form of a bimetal.

The molded one-piece trip bar **89** is journaled in vertical partitions **101** in the base **5** of the molded case circuit breaker **1** which separate the three poles of the circuit breaker. (See FIG. 6.) The trip bar **89** has actuating levers **103** for each pole extending radially downward. (See also FIGS. 2–4.) A trip lever **105** extending outwardly from the trip bar is engaged by the cradle latch plate **91** Cradle latch plate **91** is mounted for rotation about an axis parallel to the trip bar. One arm of the double acting torsion spring **95** biases the cradle latch plate **91** against the intermediate latch plate **83**. The other arm of the torsion spring **95** bears against a vertical projection **107** on the trip bar **89** to bias the trip bar in the counter clockwise direction as viewed in FIG. 2.

With the circuit breaker in the CLOSED position as shown in FIG. 2, the tension springs **57** tend to rotate the cradle **61** in the counter clockwise direction. This is resisted, however, by the cradle latch plate **91** held in place by the trip lever **105** on the trip bar **89** and acting through the intermediate latch plate **83**.

The magnetic trip assembly **97** includes a stationary magnetic structure **109**, an armature **111**, and a mechanism **113** for adjusting the magnetic trip. The planar armature **111** is bent along a horizontal axis and slotted at **115** for receipt of a pin **117** about which the armature is rotatable.

The adjusting mechanism **113** includes a helical torsion spring **119** supported on a vertical projection **121** (see FIG. 5) of the stationary magnetic structure **109**. The torsion spring **119** has one spring arm **123** which bears against an upwardly projecting tongue **125** on the armature **111** to bias the armature away from the stationary magnetic structure **109** to form a gap **127** therebetween. The other spring arm **129** of the spring **119** is engaged by an adjusting bar **131**. The adjusting bar **131** includes a depending flange **133** against which the arm **123** of the torsion spring **119** biases the tongue **125** on the armature **111**. The upper spring arms **129** of the torsion springs **119** are engaged by pivot members **135** molded into the adjusting bar **131**.

The adjusting bar **131** is supported for rectilinear, longitudinal movement by first horizontal ledges **137** on brackets **139** (see FIGS. 6–8). Upstanding pins **141** on enlarged portions **143** at each end of the adjusting bar **131** extend upward through elongated slots **144** in the ledges **137** (see FIG. 7).

Snap rings **145** received in grooves (not shown) in the pins **141** slidably connect the adjusting bar **131** to the bracket ledges **137**. Washers **147** are provided between the snap rings **145** and the ledges **137**.

A rotatably camming mechanism **149** mounted on a second raised ledge **151** on the bracket **139** adjacent one end of the adjusting bar **131** has an eccentric, depending pin **153** which engages a transverse groove **155** in the enlarged end **143** of the adjusting bar **131** (see FIG. **8**). Rotation of the camming device **149** by insertion of a tool such as a screw driver into a slot **157** provides the capability of rectilinearly moving the adjusting bar longitudinally along an adjustment axis **13** (see FIG. **6**). As can be seen from FIG. **1**, the rotatable camming device **149** is accessible through the cover **3** on the circuit breaker **1** to provide means for adjusting the position of the adjusting bar **131** without removing the cover

Since the spring arms **129** of the torsion springs **119** biasing the armatures **111** of all of the poles are engaged by pivot members **135** in the adjusting bar **131**, the bias on the armature **111** for each pole can be adjusted simultaneously by rotating the rotatable camming device **149**.

The details of the arrangement for adjustment of the torsion spring bias can best be understood by reference to FIGS. **5**, **9A** and **9B**, **10A** through **10D**, and **11**. FIG. **5** is an exploded isometric view in which the adjusting bar **131** has been rotated **90** degrees clockwise to show the configuration of the underside. The one torsion arm **123** of the torsion spring **119** has a terminal portion **159** which is bent at an angle to the main portion of the arm for engaging a groove **161** in the tongue **125** of the armature **111**.

The second torsion arm **129** of the torsion springs **119** has a first portion **163** and a second terminal portion **165** which extends at an angle from the portion **163**. As can be seen from FIGS. **9A** and **9B**, the second torsion arm **129** of torsion spring **19** bears against the pivot member **135** integrally molded into the adjusting bar **131**. With the adjustment bar in the position shown in FIG. **9a**, the first portion **163** of the torsion arm **129** bears against the pivot member **135**. This is for low settings of trip current. It can be appreciated that as the adjusting bar **131** moves rectilinearly along the adjustment axis **132** that the arm **129** of the torsion spring **119** is deflected to the left as shown in FIG. **9A** or follows the pivot member **135** as the adjusting bar moves to the right. Movement of the adjusting bar to the left as viewed in FIG. **9A** results in an increase in the bias force applied to the armature through the tongue **125**. It can also be appreciated that as the adjusting bar **131** moves to the left and the post **121** on which the spring **119** is mounted remains stationary and offset laterally from the pivot member **135**, the second torsion arm **129** slides along the pivot member **135**. A point is reached where the second terminal portion **165** of the second torsion arm **129** comes into contact with the pivot member **135** as shown in FIG. **9B**. Due to the angle between the portions **163** and **165** of the torsion arm **129**, engagement of the pivot member by the terminal portion **165** results in a greater change in the bias force applied to the armature per unit travel of the adjusting arm than when the portion **163** of the arm **129** rides on the pivot member **135**. This action can be more clearly seen from FIG. **10A** through **10D**.

FIG. **10A** illustrates the free position of the spring **119** in which neither arm **123** nor arm **129** is engaged. With no load applied to the spring, the angle θ between the axis **167** and the second torsion arm **129** is, in the exemplary embodiment, about 50 degrees. FIG. **10B** illustrates the low trip current condition where the arm **123** is engaged by the armature and the first portion **161** of the second arm **129** is engaged by the pivot member represented by the pin **135'**. Under these conditions, the angle θ is about 55 degrees. FIG. **10C** illustrates the condition of the spring for intermediate settings of trip current. In this Figure, contact between the second arm **129** of the torsion spring **119** and the pivot member **135'** is about to transfer from the first portion **163** to the second portion **165**. For intermediate settings, the angle θ varies from **55** degrees up to about 88 degrees. Finally, FIG. **10D** illustrates the maximum trip current condition where the pivot member **135'** has slid to near the end of the second portion **165** of the second arm **129** of the spring. In the exemplary embodiment, this occurs at a θ of around **88** degrees.

The effect of this bend in the second torsion arm **129** of the spring **119** is illustrated in FIG. **11** which plots a spring bias force generated versus adjusting bar position. As can be seen, the slope of the plot in the section **169** where the terminal end **165** of the second torsion arm **129** is in contact with the pivot member **135** is steeper than the portion **175** representing the condition where the first portion **163** of the torsion arm **129** is contact with the pivot member **135**. Is illustrated in FIG. **11**, the bias force with the terminal portion **165** in contact with the pivot member **135** is not only greater but changes at a greater rate with movement of the adjusting bar. This characteristic allows the circuit breaker of the invention to vary the trip current over a greater relative range than prior art circuit breakers.

In addition to varying the spring bias force applied to the armatures, the circuit breaker of the invention also adjusts the gap **127** between the armature and the fixed magnetic structure **109**. In accordance with one embodiment of the invention shown in FIGS. **5** and **9A** and **9B**, cams **173** are provided on the adjusting bar **131**. These cams **173** have camming surfaces **175** against which the tongue **125** of the armatures **111** are biased by the torsion arm **123** of the torsion spring **119**. As will be evident from FIGS. **9A** and **9B**, rectilinear movement of the adjusting bar **131** along the adjusting axis **132** results in a change in the biased position of the armature, and hence the gap between the armature and the fixed magnetic structure. In the preferred embodiment of the invention, as shown, the profile of the camming surfaces **175** are selected and positioned relative to the pivot member **135** such that as the gap increases, the spring bias force also increases. Therefore, the greatest spring bias force is applied at the maximum gap opening, and conversely minimum spring bias is applied at the minimum gap opening. The additive effect of the adjustment of the spring bias and the gap width provide a wide dynamic range for setting of trip current which permits the circuit breaker to be set for a magnetic trip anywhere between about five and ten times the rated current of the breaker.

FIG. **12** illustrates an alternative embodiment of the circuit breaker **1** in accordance in the invention illustrating a modified arrangement for adjusting the gap **127** between the armatures and the fixed magnetic structures. In this arrangement, the tongue **125'** is twisted with respect to the planar main body of the armature **111'** to form a camming surface **177**. A set screw **179** projects from the adjusting bar **131** and bears against the camming surface **177** so that movement of the adjusting bar **131'** along the adjustment axis **132'** results in adjustment of the gap. Such movement of the adjusting bar results in simultaneous adjustment of the gap for each pole, however, with the arrangement of FIG. **12**, the actual gap at any setting of the adjusting bar can be individually set by separate adjustment of the associated adjustment screw **179**.

The thermal trip for the circuit breaker **1** is set by bimetal **99** which is electrically connected to the load terminal 11*b* through a conductive member **181**. The lower end of the bimetal **99** is provided with a finger **183** which is spaced from a beveled surface **185** on the lower end of the actuating arm **103** on the trip bar **89**. The bevelled surface **185** defines a plane having the left edge as viewed in FIG. **3** closer than the right edge. Adjustment of the spacing between the finger **183** and surface **185** can be accomplished by two means. A lever arm **187** pivoted for rotation about a pin **189** engages the trip bar **89** at its lower end as seen in FIG. **6**. The upper end of the lever arm **187** is engaged by a rotatable camming device **191** mounted on a ledge **193** on the bracket **139**. The camming device **191** is similar to the device **149**. Rotation of the camming device **191** causes the lever arm **187** to rotate sliding the trip bar **89** axially. Due to the bevelled surface **185** on the actuating lever **103**, spacing between the bimetal **99** and the trip bar **89** is adjusted. The camming device **191** is also accessible through the top cover of the circuit breaker **1** as shown in FIG. **1**. Calibration of the bimetal can be effected at the factory through rotation of a screw **195**.

A current bearing conductive path between the lower end of the bimetal **99** and the upper electrical contact **27** is achieved by a flexible copper shunt **197** connected by any suitable means, for example by braising, to the lower end of the bimetal **99** and to the upper electrical contact **27** within the cross bar **49**. In this manner, an electrical path is provided through the circuit breaker **1** between the terminals **9B** and **11***b* via the lower electrical contact **25**, the upper electrical contact **27**, the flexible shunt **197**, the bimetal **99**, and the conductive member **181**.

Adjustment of the camming device **191** varies the response time of the circuit breaker to low level over currents. Since the bimetal is surrounded by the stationary magnetic structure **109**, the current conducted by the bimetal generates a magnetic field in the stationary magnetic structure which attracts the armature **111**. The spring bias and gap set by adjustment of the adjusting bar **131** through rotation of the camming device **149** adjust the level of current at which the armature is attracted to the stationary magnetic structure for the magnetic trip.

In operation, the circuit breaker **1** is set to the closed position as shown in FIG. **2**. A current in at least one of the poles which exceeds the magnetic trip setting established by the spring bias through the camming device **149**, and, if provided, the adjusting screw **179**, generates a magnetic field in the stationary magnetic structure **109** sufficient to pull the armature **111** in the associated pole toward it in a clockwise direction as viewed in FIG. **2**. The lower end of the armature rotates the trip bar in the clockwise direction until the cradle latch plate **91** slides off of the trip lever **105**. This unlatches the cradle **61** permitting the operating tension springs **57** to rotate the cradle **61** counter-clockwise as viewed in FIG. **2** which causes the toggle mechanism **47** to break over to the position shown in FIG. **3** thereby opening the set of electrical contacts **19**. As previously mentioned, this results in rotation of the cross bar **49** which opens the sets of contacts **19** on each of the poles of the circuit breaker **1**.

A persistent low level current causes the bimetal **99** to bend bringing the finger **183** into contact with the camming surface **185** or the trip lever **105** on the trip bar **89** thereby rotating the trip bar **89** and tripping the circuit breaker in the manner discussed above in connection with the magnetic trip.

With the circuit breaker tripped, the contacts are opened as shown in FIG. **4**. The circuit breaker **1** is reset by moving the handle **13** to the OFF position as shown in FIG. **3**. This rotates the cradle **61** to a position where the cradle latch plate **91** biased by the latch torsion spring **95** urges the intermediate latch plate **83** into engagement with the latching surface of the groove **79** in the cradle **61**. The latch torsion spring **95** also rotates the trip bar counter-clockwise until the cradle latch plate **91** is engaged and retained in a latched position by the lever **105** on the trip bar **89** as shown in FIG. **5**. The trip mechanism **23** is thus relatched and ready for closing of the circuit breaker by movement of the handle **13** to the CLOSED position shown in FIG. **2**. This causes the toggle mechanism **47** to rotate counter-clockwise over center, thereby closing the sets of electrical contacts **19** for each pole.

If it is desired to adjust the instantaneous trip set point of the circuit breaker **1**, a screw driver or other tool is inserted in the rotatable camming device **149** and rotated to move the adjusting bar **131** in a desired direction, the required amount. If it is desired to adjust the trip delay, a tool is inserted in the camming device **191** and rotated to pivot the lever arm **187** thereby axially displacing the trip bar **89** to adjust the gap between the finger **183** on the bimetal **99** and the beveled surface **185** on the actuating arm **103** of the trip bar **89**.

While specific embodiments of the invention have been described in detail, it will be appreciated by those skilled in the at that various modifications and alternatives to those details could be developed in light of the overall teachings of the disclosure. Accordingly, the particular arrangements disclosed are meant to be illustrative only and not limiting as to the scope of the invention which is to be given the full breadth of the appended claims and any and all equivalents thereof.

What is claimed is:

1. A circuit breaker for responding to abnormal currents in a conductor in an electrical system, comprising:

electrical contacts operable between a closed position in which a circuit is completed through the conductor and an open position in which the circuit through the conductor is interrupted;

a latchable operating mechanism operable to open said electrical contacts when unlatched;

a magnetic trip assembly comprising:

a stationary magnetic structure in which a magnetic flux is produced by current in said conductor passing through said electrical contacts;

a movable armature which is attracted to the stationary magnetic structure by said magnetic flux produced by an abnormal current of a selected value through said electrical contacts to unlatch said latchable operating mechanism and open said electrical contacts;

spring means applying a spring biasing force to said armature to bias said armature away from said stationary magnetic structure to form a gap therewith; and

spring adjusting means movable over a range of travel adjusting said biasing force to modify the selected value of abnormal current at which said armature is attracted to the fixed magnetic structure to unlatch the latchable operating mechanism, said spring adjusting means providing a first relationship between a predetermined increment of movement of the spring adjusting means and change in said biasing force over a first portion of said range of travel of the spring adjusting means and providing a second relationship between said predetermined increment of movement of the spring adjusting means and change in said biasing force over a second portion of the range of travel of said spring adjusting means, said first and second relationship being different.

2. A circuit breaker for responding to abnormal currents in a conductor in an electrical system, comprising:

electrical contacts operable between a closed position in which a circuit is completed through the conductor and an open position in which the circuit through the conductor is interrupted;

a latchable operating mechanism operable to open said electrical contacts when unlatched;

a magnetic trip assembly comprising:

a stationary magnetic structure in which a magnetic flux is produced by current in said conductor passing through said electrical contacts;

a movable armature which is attracted to the stationary magnetic structure by said magnetic flux produced by an abnormal current of a selected value through said electrical contacts to unlatch said latchable operating mechanism and open said electrical contacts;

spring means applying a spring biasing force to said armature to bias said armature away from said stationary magnetic structure to form a gap therewith;

spring adjusting means movable over a range of travel adjusting said biasing force to modify the selected value of abnormal current at which said armature is attracted to the fixed magnetic structure to unlatch the latchable operating mechanism, said spring adjusting means providing a first relationship between a movement of the spring adjusting means and change in said biasing force over a first portion of a said range of travel of the spring adjusting means and providing a second relationship between movement of the spring adjusting means and change in said biasing force over a second portion of the range of travel of said spring adjusting means; and

said spring means comprising, a torsion spring having a first torsion arm which bears against and applies said bias force to said armature, and a second torsion arm having a first portion and a second terminal portion extending at an angle to the first terminal portion, and wherein said spring adjusting means comprises a pivot member and means mounting said pivot member for reciprocal movement over said range of travel, said second torsion arm engaging and sliding along said pivot member as said pivot member reciprocates with the first portion of said second torsion arm engaging and sliding along said pivot member for the first portion of said range of travel of the spring adjusting means and with said second terminal portion of said second torsion arm engaging and sliding along said pivot member for the second portion of said range of travel of said spring adjusting means.

3. The circuit breaker of claim 2 wherein said mounting means mounts said pivot member for rectilinear reciprocal movement along an adjustment axis, wherein the first portion of the second torsion arm of said torsion spring forms a first angle with the adjustment axis of the pivot member when in engagement with said pivot member and wherein the second portion of the second torsion arm of said torsion spring forms a second angle with said adjustment axis when in engagement with said pivot member, said second angle being greater than said first so that movement of said pivot member over said second portion of its range of travel produces a greater change in said bias force per unit travel of said pivot member than does movement of the pivot member over the first portion of its range of travel.

4. A circuit breaker for responding to abnormal currents in a conductor in an electrical system, comprising:

electrical contacts operable between a closed position in which a circuit is completed through the conductor and an open position in which the circuit through the conductor is interrupted;

a latchable operating mechanism operable to open said electrical contacts when unlatched;

a magnetic trip assembly comprising:

a stationary magnetic structure in which a magnetic flux is produced by current in said conductor passing through said electrical contacts;

a movable armature which is attracted to the stationary magnetic structure by said magnetic flux produced by an abnormal current of a selected value through said electrical contacts to unlatch said latchable operating mechanism and open said electrical contacts;

spring means applying a spring biasing force to said armature to bias said armature away from said stationary magnetic structure to form a gap therewith;

spring adjusting means movable over a range of travel adjusting said biasing force to modify the selected value of abnormal current at which said armature is attracted to the fixed magnetic structure to unlatch the latchable operating mechanism, said spring adjusting means providing a first relationship between a movement of the spring adjusting means and change in said biasing force over a first portion of said range of travel of the spring adjusting means and providing a second relationship between movement of the spring adjusting means and change in said biasing force over a second portion of the range of travel of said spring adjusting means; and

gap adjusting means adjusting said gap between a minimum spacing and a maximum spacing between said movable armature and said fixed magnetic structure to also modify the selected level of abnormal current at which said movable armature is attracted to the fixed magnetic structure to unlatch the latchable operating mechanism.

5. The circuit breaker of claim 4 including an adjusting member carrying both said spring adjusting means and said gap adjusting means to simultaneously adjust said spring biasing force and said gap.

6. The circuit breaker of claim 5 wherein said gap adjusting means comprises a cam carried by aid adjusting member and having a camming surface against which said movable armature is biased by said spring means to set said gap, said camming surface being shaped to adjust said gap through movement of the adjusting member relative to said armature.

7. The circuit breaker of claim 6 wherein said armature is pivoted about a pivot axis for rotation toward and away from said stationary magnetic structure, wherein said adjusting member is elongated and mounted for generally rectilinear movement along an adjustment axis generally parallel to said pivot axis to

provide said range of travel of said spring adjusting means, wherein said spring means is a torsion spring having a first torsion arm which bears against said armature and a second torsion arm having a first portion and a second terminal portion extending at an angle to the first portion, and wherein said spring adjusting means comprises a pivot member mounted on said elongated adjusting member which said second torsion arm engages and slides along as said elongated adjusting member moves rectilinearly, said first portion of said second torsion arm engaging and sliding along aid pivot member for the first portion of the range of travel of the adjusting member and the second terminal portion of said second torsion arm engaging sliding along said pivot member for the second portion of said range of travel of the adjusting member.

8. The circuit breaker of claim **7** wherein the first portion of the second torsion arm of said torsion spring forms a first angle with the adjustment axis of the adjusting member when in engagement with said pivot member and wherein the second portion of the second torsion arm of said torsion spring forms a second angle with said adjustment axis when in engagement with said pivot member, said second angle being greater than said first so that movement of said adjusting member over said second portion of said range of travel produces a greater change in said bias force per unit travel of said adjusting member than does movement of the adjusting member over the first portion of said range of travel.

9. The circuit breaker of claim **8** wherein said camming surface is located on said adjusting member and is shaped to set said gap toward the maximum spacing between the movable armature and the fixed magnetic structure when said second portion of said second torsion arm of the torsion spring engages said pivot member and to set said gap toward said minimum spacing between the movable armature and the fixed magnetic structure when said first portion of said second torsion arm of the torsion spring engages said pivot member.

10. A circuit breaker for responding to abnormal currents in phase conductors associated with each phase of a three phase electrical system comprising:

- a set of electrical contacts for each phase conductor of the three phase electrical system completing an electrical circuit through the associated phase conductor when closed and interrupting the electrical circuit when open;
- a latchable spring powered operating mechanism operable to open all of said sets of electrical contacts when unlatched;
- a trip bar rotatable from a biased position to a trip position to unlatch said operating mechanism;
- a magnetic trip assembly associated with each phase conductor of the three phase electric system with each assembly comprising:
  - a stationary magnetic structure;
  - a pivotally mounted armature rotatable about a pivot axis toward the stationary magnetic structure to rotate the trip bar to the trip position in response to an abnormal current through the associated phase conductor; and
  - torsion spring means having a first torsion arm biasing said armature away from said stationary magnetic structure to form a gap therebetween and having a second torsion arm with a first portion and a second terminal portion extending at an angle from the first portion of the second torsion arm; and
- an adjusting member mounted for reciprocal generally rectilinear movement over a range of travel along an adjustment axis generally parallel to the pivot axes of said armatures, said adjusting member carrying a pivot member associated with each torsion spring, the first portion of the second torsion arm of each torsion spring engaging and sliding along the associated pivot member for a first portion of the travel range of said adjusting member and the second terminal portion of said second torsion arm of each torsion spring engaging and sliding along the associated pivot member for a second portion of the range of travel of said adjusting member.

11. A circuit breaker for responding to abnormal currents in phase conductors associated with each phase of a three phase electrical system comprising:

- a set of electrical contacts for each phase conductor of the three phase electrical system completing an electrical circuit through the associated phase conductor when closed and interrupting the electrical circuit when open;
- a latchable spring powered operating mechanism operable to open all of said sets of electrical contacts when unlatched;
- a trip bar rotatable from a biased position to a trip position to unlatch said operating mechanism;
- a magnetic trip assembly associated with each phase conductor of the three phase electric system with each assembly comprising:
  - a stationary magnetic structure;
  - a pivotally mounted armature rotatable about a pivot axis toward the stationary magnetic structure to rotate the trip bar to the trip position in response to an abnormal current through the associated phase conductor; and
  - torsion spring means having a first torsion arm biasing said armature away from said stationary magnetic structure to form a gap therebetween and having a second torsion arm with a first portion and a second terminal portion extending at an angle from the first portion of the second torsion arm; and
  - an adjusting member mounted for reciprocal generally rectilinear movement over a range of travel along an adjustment axis generally parallel to the pivot axes of said armatures, said adjusting member carrying a pivot member associated with each torsion spring, the first portion of the second torsion arm of each torsion spring engaging and sliding along the associated pivot member for a first portion of the travel range of said adjusting member and the second terminal portion of said second torsion arm of each torsion spring engaging and sliding along the associated pivot member for a second portion of the range of travel of said adjusting member; and
- a cam associated with each armature mounted on the adjusting member, each cam having a camming surface against which the associated armature is biased by the first torsion arm of the associated torsion spring, said camming surface of each cam having a profile which adjusts the gap between the associated armature and stationary magnetic structure from a maximum adjacent one end of said range of travel of said adjusting member and a minimum adjacent the other end of said range of travel of said adjusting member.

12. The circuit breaker of claim 11 wherein said first portion of the second torsion arm of each torsion spring forms a first angle with the adjustment axis of said adjusting member when said first portion is in engagement with said pivot member, and wherein said second terminal portion of said second torsion arm of said torsion spring forms a second angle with the adjustment axis of said adjusting member when said second portion is in engagement with said pivot member, said second angle being greater than said first angle so that movement of said adjusting member over said second portion of said range of travel produces a greater change in said bias force per unit travel of said adjusting member than does movement of the adjusting member over the first portion of said range of travel.

13. The circuit breaker of claim 12 wherein said second terminal portion of said second torsion arm of the torsion spring engages said pivot member when said adjusting member is adjacent said one end of said range of travel of said adjusting member and wherein said first portion of the second arm of said torsion spring engages said pivot member when said adjusting member is adjacent said other end of said range of travel of said adjusting member such that the greater change in said bias force applied to the armatures per unit travel of said adjusting member occurs with the gaps between the armatures and the stationary magnetic structures near the maximum.

14. A circuit breaker for responding to abnormal currents in phase conductors, associated with each phase of a three phase electrical system comprising:

a set of electrical contacts for each phase conductor of the three phase electrical system completing an electrical circuit through the associated phase conductor when closed and interrupting the electrical circuit when open;

a latchable spring powered operating mechanism operable to open all of said sets of electrical contacts when unlatched;

a trip bar rotatable from a biased position to a trip position to unlatch said operating mechanism;

a magnetic trip assembly associated with each phase conductor of the three phase electric system with each assembly comprising:

a stationary magnetic structure;

a pivotally mounted armature rotatable about a pivot axis toward the stationary magnetic structure to rotate the trip bar to the trip position in response to an abnormal current through the associated phase conductor; and

torsion spring means having a first torsion arm biasing said armature away from said stationary magnetic structure to form a gap therebetween and having a second torsion arm with a first portion and a second terminal portion extending at an angle from the first portion of the second torsion arm; and

an adjusting member mounted for reciprocal generally rectilinear movement over a range of travel along an adjustment axis generally parallel to the pivot axes of said armatures, said adjusting member carrying a pivot member associated with each torsion spring, the first portion of the second torsion arm of each torsion spring engaging and sliding along the associated pivot member for a first portion of the travel range of said adjusting member and the second terminal portion of said second torsion arm of each torsion spring engaging and sliding along the associated pivot member for a second portion of the range of travel of said adjusting member; and

said armatures each having an integral camming surface which is inclined to the pivot axis of the armature and wherein said adjusting member has a projection associated with each armature against which the associated armature is biased by a torsion spring to set said gap, said project is sliding along the associated camming surface to adjust said gap as the adjusting member moves generally rectilinearly over said range of travel.

15. The circuit breaker of claim 14 wherein said projections are screws which can be individually threaded toward and away from the associated armature to individually adjust the gap for each phase.

* * * * *